Appendix C

Economic Impact Estimates – High-Global Warming Potential Stationary Source Refrigerant Management Program

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1. Summary

The proposed Refrigeration Management Program regulation impacts facilities that utilize stationary refrigeration equipment with greater than or equal to 50 pounds of high global warming potential (GWP) refrigerant. Facilities are categorized into three refrigerant charge size categories based on the amount of refrigerant required by individual systems used by a facility; greater than or equal to 50 lbs, but less than 200 lbs (small systems); greater than or equal to 200 lbs, but less than 2,000 lbs (medium systems); and 2,000 lbs and greater (large systems). The small systems are typified by small condensing unit refrigeration systems. The medium systems are mainly centralized refrigeration systems and cold storage systems. The large systems are mainly cold storage systems, process cooling systems, and some centralized refrigeration systems. Facilities are categorized by the largest system at the facility; i.e. a facility with both large and medium systems is categorized as a large facility. The resulting characterization of current refrigerant use patterns by facility types and statewide facility number estimates were used to calculate the extrapolated statewide carbon dioxide equivalent (CO_2E) emissions. For a full description of the affected facilities, see Appendix B (California Facilities and Greenhouse Gas Emissions Inventory).

This appendix presents estimates of the costs and cost savings of the proposed high-GWP stationary source refrigerant management program regulation. The economic benefits presented are limited to the cost savings from avoided refrigerant losses. Some energy savings are expected from more optimized operation due to maintaining the proper refrigerant charge and routine maintenance; however these benefits are not quantified at this time. Energy savings would also likely reduce criteria pollutants in addition to emissions of CO_2 from power generation. The economic benefits from mitigated climate impacts from reduced use of high-GWP refrigerants are also not incorporated into these estimates. In these analyses all costs are estimated in constant 2008 dollars.

Costs of refrigerants are expected to rise as hydrochlorofluorocarbon (HCFC) and chlorofluorocarbon (CFC) refrigerants (also referred to as ozone depleting substances [ODS]) are phased out, and if production and import of hydrofluorocarbons (HFC) are restricted under future legislation. However, the rate of price increases from present day to 2020 is unknown. The change in the uses of these refrigerants could only be broadly estimated based on linear interpolation of estimates from the United States Environmental Protection Agency (U.S. EPA) Vintaging Model for 2010 and 2020. As a result, this analysis provides a conservative estimate of refrigerant prices by using an average of current prices of the refrigerants available in 2008.

An important aspect of the proposed rule is that the mandated repairs, which result in the emissions benefits, also result in cost savings that exceed the compliance costs. However, the costs and benefits for any specific company of industry may vary widely from the overall average. For example, the gross cost to regulated

entities for 2020 is estimated to be $49 million per year. These estimated costs are more than offset by annual refrigerant savings estimated at $68 million based on current refrigerant prices for a net annual savings of $19 million. The average cost-effectiveness of the proposal is estimated to be a savings of $2 per metric ton CO_2 equivalent ($MTCO_2E$) in the year 2020 after the proposed regulation is fully implemented and for consistency with AB32 target dates. This is a conservative estimate in that it does not account for rising refrigerant prices, energy savings due to optimized system operation, or benefits from mitigated climate impacts.

2. Introduction

The Refrigerant Management Program proposed regulation consists of two primary components: 1) facility reporting and refrigeration system maintenance and leak repair; and 2) refrigerant sale, use, and disposal. Economic costs and benefits analyses were conducted separately for the individual components. The economic analyses reported in this appendix estimate the total costs of the regulation to the regulated community and the fiscal impacts to the enforcement agencies. The economic benefits presented are limited to the cost savings from avoided refrigerant losses.

Costs to regulated facilities and businesses are estimated for the implementation period of 2011 to 2020. The analyses are organized by facilities with large, medium, and small refrigeration systems and provide the costs and benefits by the size of the system and the type of refrigerant used: HFC-only, ODS-only, and both HFC and ODS.

The cost and economic benefit analyses rely on input from the Air Resources Board (ARB) emissions inventory and potential emission reductions outlined in Appendix B, cost and other data from technical literature, input from equipment manufacturers and other stakeholders, and industry surveys. All uncertainties outlined in Appendix B impact the uncertainty of the total cost estimates and economic benefits in this analysis. To evaluate and understand the impacts of other sources of uncertainty, additional data were collected and reviewed from as many sources as possible including stakeholders, manufacturers, and air agencies (U.S. EPA, California air pollution control districts, etc.)

For all labor estimates an hourly labor rate of $75 is used. This is a fully loaded average labor rate representing input from ICF International, stakeholders, the air quality control districts, and the ARB.

Businesses impacted by this regulation include facilities with refrigeration systems containing 50 lbs or more of high-GWP refrigerants. These include: supermarkets, meat packers, warehouses used for cold storage, food preparation and processing, hotels, medical facilities, institutions (universities, laboratories, etc.), process cooling facilities, etc. Additional details about these industries and the refrigeration systems they use are in Appendix B. The proposed regulation also impacts other service and sales businesses including: refrigeration and air-conditioning (R/AC)

contractors, and technicians; and refrigerant reclaimers, distributors, and wholesalers.

No change is expected in business competitiveness. It is possible some R/AC servicing businesses may be created or existing businesses expanded as a result of the possible increase in demand for U.S. EPA certified technicians and for manufacturing and installation of leak detection monitoring systems.

Estimated leak repair costs represent the difference between immediate repairs and repairs at the time the loss of refrigerant exceeds 35% of the charge (business-as-usual; BAU) at the refrigerant loss rate indicated by staff research for the refrigeration system type and size. This is similar to expanding on the U.S. EPA regulations promulgated under Section 608 of the Clean Air Act (Rule 608) whereby repairs of ODS-containing refrigeration systems are mandated when they have leaked 35% of the full refrigerant charge in the preceding year (12 month rolling average). The interest cost (or lost opportunity cost) at 5% per year of the gross repair cost (parts, labor, and refrigerant recharge) is attributed to the rule.

The post-rule implementation scenario leak repair costs reflect a portion of the total cost of leak repairs since the proposed rule does not create a need for leak repair but only requires that leak repairs be completed within 14 days of detection. Under the BAU scenario 100% of all leak repair costs are incurred at some point to maintain refrigeration system operations and preserve refrigerated product. These costs may be incurred immediately after detection of a leak based on best practices or, as often happens in the BAU scenario, after months or years of deferred maintenance, often with top-offs of refrigerant rather than timely repairs. Based on repairs completed on the BAU time line the total costs are incurred and the BAU emissions and BAU average leak rates result.

The annual discount rate of 5% used in this analysis is representative of the cost of money when high-risk technologies and activities are not involved and is consistent with cost assumption of the AB 32 Scoping Plan. The Scoping Plan's analysis of costs and savings included a uniform real discount rate of 5% to estimate the cost of money for all proposed measures and provided the first step towards annualizing the upfront or capital expenditures. Sensitivity analyses indicated that even using a much higher cost of money (up to 20%), the measure is still cost effective.

The local air districts will be impacted by the need for additional inspection and enforcement resources. The costs to the ARB will include enforcement and inspection costs not assumed by the districts and costs to initiate and maintain a web-based reporting system and database as well as processing and maintaining the annual industry reports. These costs are expected to be recovered through the implementation fees imposed on the impacted facilities.

Positions required for administration of the Refrigerant Management Program may be ARB positions or positions throughout Air Districts that would be funded with ARB funds available through receipt of implementation fees.

3. Economic Cost and Cost Savings Estimates (Facility Reporting and Leak Repair Component)

This section presents the underlying data and calculations that were used to estimate the overall costs of the proposed regulation to the regulated community. It includes a discussion of the emissions input data as well as the costs of each key element of the program including the implementation fee, reporting and recordkeeping costs, automatic leak detection system annual audits, refrigeration system leak inspections, automatic leak detection system capital and operating costs, and leak repair costs.

Costs and savings of the regulation are calculated using the emissions inventory data and projected emission reduction estimates provided in Appendix B and additional economic input variables discussed below. The resulting estimated costs are tiered by system size to reflect different workload demands (e.g. monitoring, inspection, etc.). Under the proposed rule the annual implementation fee and reporting requirements are phased in depending on the system size. The refrigerant leak detection and monitoring provisions become effective on January 1, 2011. The leak repair and recordkeeping provisions commence upon the effective date of the regulation for all applicable systems.

The cost related input factors used in the economic model, discussed below and listed in Table 1, are based on literature review, a survey of refrigeration and air-conditioning service contractors, certified technicians, and discussions with stakeholders.

Table 1: Economic estimates input factors

	Facilities with small systems	**Facilities with medium systems**	**Facilities with large systems**
Annual implementation fee (per facility)	0	$170	$370
Annual reporting and recordkeeping costs (per facility)	$115	$422	$488
Automatic leak detection annual audit, quarterly inspection, or annual inspection costs (per system)	$75 per system	$300 per system	$150 per system
Automatic leak detection capital costs (per system)	N/A	N/A	$917/year per system (capital and installation cost) annualized over 12 years ($8,130 at 5% real discount rate)
Automatic leak detection operational costs (per system)	N/A	N/A	$720
Leak repair costs (base cost per leaking system) *	$62	$79	$328
Post-repair refrigerant recharge (per leaking system)	6 lbs ($67)	69 lbs ($758)	447 lbs ($4,910)

*Leak repairs costs provided as 5% real discount rate per year.

The refrigerant cost estimate ($11 per pound) is based on discussions with stakeholders and is derived from the average of a suite of refrigerants currently in common use. The cost of the individual refrigerants currently varies from $4.50 to $23.00 per pound. All costs and savings are stated in constant 2008 dollars.

The growth of the number of facilities and systems was estimated at 1% per year.

The cost calculation model used estimates the fiscal impact of the proposed regulation on facilities with average configurations (as outlined in Appendix B): small facilities with approximately 5 systems in the small refrigerant charge size category, medium facilities with approximately 5 systems in the medium refrigerant charge size category, and large facilities with approximately 2 systems in the large refrigerant charge size category. In practice facilities with more than one refrigeration system typically have a mixture of system sizes, i.e. many "large" facilities that have large sized systems will also often have medium and small size systems (and likewise, medium facilities will often have smaller systems). It is recognized that facilities with the average configuration modeled do not necessarily commonly exist in practice. The approach taken here provides a means of calculating the average impacts of the costs of the rule. The costs associated with several case studies of real-world, specific facility configurations were also calculated and are presented later in this document.

Recurring annual costs – Facilities will incur annual costs for implementation fees, reporting and recordkeeping, and leak inspections or annual leak detection monitoring system audits.

Equation 1: statewide recurring annual costs

$$C_a = N_f \times (F_a + R + L_c \times N_s)$$

C_a = statewide recurring annual costs
N_f = number of affected facilities
F_a = annual implementation fees per facility
R = reporting expenses per facility
L_c = annual and quarterly leak inspection or annual leak detection monitoring system audits and recordkeeping
N_s = number of systems per facility

The implementation fees and reporting costs are single costs per facility based on the largest system at the facility. The leak inspection or leak detection system audits and the costs of keeping their associated records are calculated as a cost per system at the facility (i.e. if a facility has 3 refrigeration systems it will incur a single annual implementation fee that covers the entire facility, based on the largest system at the facility, a single reporting cost also covers the entire facility, and 3 times the system leak inspection or leak detection system audit and recordkeeping costs listed in Table 1 [once for each system]).

Under the proposed rule the annual implementation fee and reporting requirements are phased in depending on the system size: facilities with large refrigeration systems submit their first report (covering calendar year 2011) and payment of the implementation fee in early 2012 (due by March 1, 2012) with subsequent reports and payments annually thereafter. Facilities with medium size refrigeration systems (but no large sized systems) would begin reporting for the year 2013 with the report and implementation fee payment due by March 1, 2014 with subsequent reports and payments annually thereafter. Facilities with only small refrigeration systems (i.e., they do not have medium or large systems) will not be subject to either the reporting or annual implementation fee requirements of the rule although they will be required to register beginning in 2016.

All facilities with refrigeration systems covered by this regulation will be required to conduct leak inspections of their refrigeration systems and to maintain records of their repairs and refrigerant transactions and have those records available for enforcement inspectors.

- Annual implementation fee – Each facility with a large or medium refrigeration system will pay an annual implementation fee to the ARB which will be used by the enforcing agency (either the local air pollution control district or the ARB) to recoup their implementation, inspection, and enforcement costs (staff training expenses, reporting system development, and inspection and recordkeeping time, etc.). The implementation fee would be collected at the time the facility registration for operation is submitted or with the annual renewals. Facilities with small refrigeration systems only (i.e., they do not have medium or large systems) will not be subject to the annual implementation fee requirements of the rule, although they will be required to register for operation by 2016 and maintain records of refrigerant leaks.

  The proposed fee amounts are based on input from California Air Pollution Control Officers Association (CAPCOA)[1] and the ARB Enforcement Division estimates of their time and materials needed to conduct inspections. The time needed includes pre-inspection time for facility records review; on-site equipment inspection; review of equipment service records and leak repair records; review of refrigerant purchase, use, and shipping records; travel planning; and report writing. The fees are also based on the expectation that all facilities will not need to be inspected by the enforcement agency each year. It was assumed that compliance could be maintained with periodic enforcement inspections prioritized on facilities' potential or demonstrated leak risk, i.e. those facilities with a larger charge (greater potential emissions in the case of a leak), equipment type that is more prone to leaks, and with a higher leak rate demonstrated by their annual report. Facilities whose annual report indicates frequent leaks and substantial emissions may receive a higher priority and be inspected more frequently.

[1] Memo from CAPCOA to Anthony Andreoni, November 4, 2008

- Reporting and recordkeeping costs – Although reporting and recordkeeping costs are not listed together in Equation 1, they are discussed together in this section since they are closely related.

  The proposed regulation will require each facility to maintain records of their repairs, refrigerant use and purchases, etc. The facilities with large and medium size systems will be required to report their leak inspections, service and maintenance, refrigerant leak repairs, and refrigerant consumption by device or system. Additionally, these facilities will be required to report an annual summary of refrigerant purchased, charged into systems, and recovered from systems. Facilities with only small systems will not be required to submit annual reports; however, they will be required to retain the records and have them available for ARB or local air district inspectors. The calculated costs assume that the ARB will initiate and maintain a web-based reporting system and database. The reporting and recordkeeping costs reflect time costs for the facility to maintain records and submit the annual report.

  Many facilities, especially those with large systems already have a process in place for tracking repairs, refrigerant use, and leak rates. The ARB is developing a system whereby the reports will be efficiently transferred to a centralized database for access by ARB and, where appropriate, the air districts. For large facilities it is estimated to take 15 minutes per system leak to record leaks, 15 minutes per month per monitored system to maintain records of the automatic leak detection system, and 10 minutes once per year to electronically submit the report. For medium facilities it is estimated to take 15 minutes per system leak to record leaks, 15 minutes 4 times per year to maintain records of the leak inspections, and 10 minutes once per year to submit the report. For small facilities it is estimated to take 15 minutes per system leak to maintain repair records and 15 minutes once per year for each system to maintain the leak inspection records. The $75 labor rate was used in these calculations.

Table 2: Estimated reporting and recordkeeping costs per large facility

Large Systems	**Minutes**	**Occurrences per Year**	**Systems / Units**	**Percent Leaking Systems**	**Hours**
Recordkeeping - Recording Leaks	15	(variable by probability of leak)	2	67.5%	0.3
Recordkeeping - Automatic Leak Detection System Performance Records	15	12	2		6.0
Reporting	10	1			0.2
Total Hours					6.5
Total Costs (@ $75 / hour)					$488

The total reporting and recordkeeping costs per facility are outlined in Table 1. Using large systems as an example, Table 2 outlines how these costs are calculated.

- Leak inspections and leak detection system audits – Facilities with large refrigeration systems will be required to use an automated system to detect leaks (usually a continuous monitor, but other automatic leak detection systems or procedures will be allowed). Facilities with medium size systems will be required to conduct leak inspections quarterly. Facilities with small systems only will be required to conduct inspections annually. The automatic leak detection annual monitoring costs included in these analyses reflect the costs for an annual audit of the automatic leak detection monitoring system. It is estimated that an audit of a large system leak detection system will take two hours per system to complete.

  In reviewing the cost of leak inspections, the ARB staff compiled estimates based on two very different perspectives to inform cost estimates. One perspective was provided by ICF International and characterized the cost of inspection by in-house vs. external inspectors. The ICF International cost estimate was based on two to six hours of inspection time required per facility (on average, 2 to 5 systems inspected either annually or quarterly) and ranged from $93 to $561 per inspection. The low ICF International estimate represents a two-hour in-house inspection and the higher estimate represents a six-hour inspection by contracted inspectors and includes profits and fees by the contracting company.

  The other estimate was provided by CAPCOA and represented the cost of a leak inspection for enforcement purposes by the ARB or the air district (the local air quality management district or air pollution control district) inspectors. ARB and CAPCOA estimates were based on three to six hours per facility (on average, 2 to 5 systems inspected either annually or quarterly) and ranged from $195 to $682 per inspection.

  The costs used in these analyses were $75 to $300 per system per year reflecting one to four hours at a $75 per hour labor rate. The primary source of the uncertainty in this estimate is the assumption that salaries for inspection staff represent an in-house, hourly salary or the salary of a contracted certified technician.

  An inspection of a medium system is estimated to take one hour per system each quarter, and an inspection of a small system is estimated to take one hour per system once per year. The $75/hour labor rate was used in these calculations. Medium and small facilities may substitute automatic leak detection for the quarterly or annual inspections.

  Table 3 outlines how the total automatic leak detection annual audit and leak inspection costs are calculated. The total estimated costs are outlined in Table 1.

Table 3: Automatic leak detection system audit and leak inspection costs per system

Leak Inspection	Hours	Times per Year	Total Hours per System	Total Cost per System
Automatic Leak Detection Audit	2	1	2.0	$150
Medium Sized Leak Inspections	1	4	4.0	$300
Small Sized Leak Inspections	1	1	1.0	$75

Automatic leak detection capital and operational costs – Facilities with large refrigeration systems will be required to have a mechanism for automatic leak detection and monitoring of each large system. This will primarily be a continuous monitoring system measuring the presence of refrigerant in the air surrounding the components of the refrigeration system, but other continuous leak detection mechanisms and procedures will be allowed. In addition, facilities with medium or small systems may substitute automatic leak detection for the quarterly or annual system inspections. If a facility with medium or small systems is required to have a monitoring system to comply with health and safety rules this option may be beneficial. It may also be beneficial for facilities with large systems requiring automatic leak detection systems along with medium and/or small systems to include those systems in the automatic leak detection system.

The automatic leak detection system requirements of the proposed regulation can be met by installing a direct system that detects the presence of refrigerant in ambient air or an indirect system that indicates a refrigerant leak by interpreting parametric measurements of the refrigeration system. The analyses focus on direct systems for a representation of the likely costs for an automatic leak detection system. In some cases the indirect (parametric monitoring) may be more feasible depending on the refrigeration system design (systems with outdoor components, etc).

Estimated costs related to automatic leak detection are based on a system that will meet all requirements of the rule and were confirmed through discussions with manufacturers. The ARB also contracted with ICF International for input into the analysis of the costs of automatic leak detection systems required by the proposed rule based on their experience in refrigerant management and participation in the development of the U.S. EPA Vintaging Model. The primary sources of uncertainty in the estimated costs of automatic leak detection are the type of equipment purchased and the installation of the monitoring system. To be conservative, this analysis assumes that each large refrigeration system would require a separate monitoring system. There is likely some unknown scalability factor in which multiple refrigeration systems can be monitored by a single monitoring system, this will depend on the capabilities of the monitoring system purchased and how it is installed.

The installation cost data reflects a best estimate of the capital cost to purchase an automatic leak detection system based on market studies conducted for this analysis[2]. The estimated capital costs of $8,130 for an eight sensor system are annualized over a twelve-year projected life of the monitoring system at a 5% real discount rate ($917/year). This cost represents an estimated average cost which takes into account: 1) the cost of a new monitoring system on each refrigeration system (estimated at between $10,000 to $11,000); 2) the cost of a somewhat larger system that is capable of monitoring more than one refrigeration system at the facility (estimated at $12,000 to $15,000 for up to 16 sensors; i.e. $6,000 to $7,500 per system to monitor two systems); and 3) the cost of enhancing an existing system installed to monitor the machine room for health and safety purposes (adding capacity and sensors to a monitoring system designed to alert the operator of concentrations of refrigerant potentially dangerous to worker health and safety [one or more sensors usually in the lowest area of the machine room where refrigerant gases would collect if present] to a monitoring systems with sensors placed to promptly detect leaks [estimated at $3,000 to upgrade control panel and new/additional sensors]).

Although one automatic leak detection system per refrigeration system was modeled, each facility will likely have a somewhat different configuration. In some applications a single monitoring system may be sufficient to monitor for leaks on several refrigeration systems, depending on refrigeration system and monitoring system configurations, sensor design and placement, and the design of the systems. Facilities may also choose to configure the monitoring systems to monitor zones of the facility; for example: one system may monitor all equipment in the equipment room while another monitoring system may monitor for leaks in the evaporators, etc.[3]

The typical monitoring system requires annual maintenance. The maintenance costs include the replacement of filters and/or calibration of the sensors, depending on the design of the system. These costs are typically approximately $90 per monitoring point per year ($720/year for the average 8 point monitoring system).[4]

Equation 2: annual automatic leak detection and monitoring costs

$$C_m = N_f \times (N_s \times (M + I))$$

C_m = automatic leak detection and monitoring costs
N_f = number of affected facilities
N_s = number of systems per facility requiring automatic leak detection systems
M = annual cost of maintaining the system
I = capital cost to install a system (annualized)

[2] ICF to ARB, October 21, 2008
[3] Lewis, Kimberly, Guidelines for Refrigerant Leak Monitor Installation, RSES Journal, April 2002.
[4] ICF to ARB October 21, 2008 and discussions with equipment manufacturers

Leak repair costs – Refrigeration system leaks may be categorized as smaller, operating leaks or catastrophic leaks. While the catastrophic leak may result in the sudden loss of much or all of the refrigerant charge, the operating leaks account for most of the leaks that occur and the majority of the refrigerant emissions.[5] Regular leak inspections or automatic leak detection systems are useful in finding operating leaks promptly, facilitating prompt repair and minimizing the amount of refrigerant lost. Under this rule both the operating leaks and catastrophic leaks would be repaired immediately upon discovery.

All facilities and systems will be subject to the leak repair requirements of the regulation beginning with the effective date of the regulation. The repair costs are calculated as the base cost of making the repair and the refrigerant to recharge the system to replace the refrigerant lost in the leak. Since the leaking systems eventually need to be repaired to continue to operate without regard to this rule, the repair costs (both base costs and cost of the refrigerant to recharge the system after the repairs) attributable to the rule are based on the time cost of funds at 5% per year real discount rate and the length of time that the leak would be expected to continue under BAU until the amount of refrigerant leaked would equal 35% as opposed to repair of the leak upon the first indication that the leak has occurred.

Leak repair costs are based on research conducted on behalf of the ARB by ICF International and discussions with stakeholders. The ARB conducted a survey of refrigeration and air-conditioning service contractors and technicians to validate prior research and discussions.

Annual leak repair costs presented in Table 1 are divided into three ranges based on refrigeration system size. It is assumed that repairs on a small system will be relatively simple while medium and large systems will require progressively more extensive repairs when a leak occurs. Leak repair costs include two components: the base cost of making the repair (parts, labor, and recovery of remaining refrigerant in the system) and the refrigerant needed to recharge the system to its nominal operating charge. Table 4 shows that the base annual repair costs (labor, parts, and refrigerant recovery) are $900, $1,550, and $2,450 for repair scenarios projected for the small, medium, and large systems. The base costs include 8, 12, and 16 hours of labor at $75/hour; $100, $300, and $600 in parts; and $200, $350, and $650 for refrigerant recovery for small, medium, and large systems respectively.[6, 7]

The refrigerant needed to recharge the system following a repair is calculated from the modeled average target leak amount per system of that size and type and a refrigerant cost of $11 per pound. The target leak amount represents a realistic and achievable reduction in leaks projected as a result of the leak detection and monitoring and best management practices provisions of this rule. Refrigerant savings are the difference between the BAU leakage and the target leak amount (Table 5). The recharge for large systems is, on average, about 447 pounds per

[5] EPA-600/R-97-039, April 1997
[6] ICF to ARB November 10, 2008
[7] ARB technician survey results

system per year (see Appendix B for more details); down from 1090 pounds based on the BAU leak rate; a savings of 642 pounds ($7,060).

In the model for this rule the BAU repairs would be initiated when the projected refrigerant loss reaches 35%. The time factor of the cost calculation is calculated as the number of years until the refrigerant leak reaches 35%. The interest cost (or lost opportunity cost) at 5% per year of the gross repair cost (parts, labor, and refrigerant recharge) is attributed to the rule. For example: a typical medium system containing 689 pounds of refrigerant which leaks an average of 17% of the charge per year under BAU would lose 119 pounds per year. After approximately two years (2.1 years) the refrigerant loss would equal 35% of the charge; therefore a BAU repair would be made at that time. Under the regulation requirements the repair would have been made immediately upon the first indication of a leak rather than at the later date. The cost attributable to the regulation would be the cost of borrowing (or lost opportunity cost) for 2.1 years at 5% per year; or approximately 10% of the gross cost of the repair. The cost of repairs attributable to the rule when the refrigerant loss equals or exceeds 35% in less than one year are calculated at 5% of the gross repair cost.

Table 6 illustrates the effective cost of funds of incurring the cost of the repairs immediately and is the portion of the repair costs that are attributed to the rule. Table 6 shows average values, specific values of the cost of funds were used in the calculations whenever possible.

Table 4: Base annual repair costs

	Labor hours / cost (@ $75 per hour)	**Parts**	**Recovery of remaining refrigerant prior to repair**	**Total labor, parts, and recovery**
Small systems	8 hrs / $600	$100	$200	$900
Medium systems	12 hrs / $900	$300	$350	$1,550
Large systems	16 hrs / $1,200	$600	$650	$2,450

Table 5: Annual leak repair refrigerant costs and savings

	BAU average annual refrigerant leak (lbs)	**Target average annual refrigerant leak ***	**Annual refrigerant savings (lbs)**	**Annual refrigerant cost savings (@ $11 / lb)**
Small systems	18	6	12	$127
Medium systems	119	69	50	$548
Large systems	1090	447	642	$7,060

* Expected amount needed to recharge following repair (lbs)

Table 6: Calculation of effective cost of funds for the average facility leak rate

	Annual average leak rate	Average charge (lbs)	Time frame	Effective cost of funds
Small systems	14%	122	2.4 years	12.1%
Medium systems	17%	689	2.0 years	10.2%
Large systems	23%	4663	1.5 years	7.5%

Equation 3: annual leak repair costs

$$C_r = (N_s \times L_s \times C_{rt}) \times (35\% / L_r) \times 5\%$$

C_r = leak repair cost
N_s = number of systems
L_s = percent of systems leaking
C_{rt} = repair cost (parts, labor, and refrigerant to recharge system)
L_r = average annual leak rate

Statewide gross annual cost – The gross cost is the sum of all costs incurred in a given year.

Equation 4: statewide gross annual costs

$$C_g = C_a + C_m + C_r$$

C_g = statewide gross annual costs
C_a = statewide recurring annual costs
C_m = annual automatic leak detection and monitoring costs
C_r = annual leak repair cost

Refrigerant savings – Because the anticipated result of the proposed rule is the transition from the BAU average leak rate for any specific refrigeration type and refrigerant charge size category to the post rule implementation average leak rate, the costs and emissions that reflect each scenario are used to estimate cost effectiveness. The refrigerant savings arise as a result of earlier leak repairs following a transition to the post-rule implementation average leak rates. This change in leak rates results in estimated emission reductions due to the difference between the BAU emissions and the post rule implementation emissions.

Equation 5: refrigerant savings

$$R_s = (L_{BAU} - L_{r1}) \times P_r$$

R_s = annual refrigerant savings
L_{BAU} = annual refrigerant loss under BAU
L_{r1} = reduced refrigerant needed per year
P_r = refrigerant price

Statewide net annual cost – The net annual cost is the gross annual cost minus the savings due to reduced refrigerant use because the leaks are repaired earlier as compared to the business as usual scenario.

Equation 6: statewide net annual costs

$$C_n = C_g - R_s$$

C_n = statewide net annual costs
C_g = statewide gross annual costs
R_s = annual refrigerant savings

Although some energy savings are expected from more optimized operation due to maintaining the proper charge and routine maintenance; these benefits are not quantified at this time and not included in Equation 6. The economic benefits associated with mitigated climate impacts are also not included.

Cost-effectiveness (C/E) – The cost-effectiveness is the ratio of the net costs to the emission reductions expected due to the enhanced leak detection and repair requirements of the rule, in dollars per metric ton of CO_2E ($ / $MTCO_2E$).

Equation 7: cost-effectiveness (C/E)

$$C_e = C_n / L_{r2}$$

C_e = cost-effectiveness ($ / $MTCO_2E$)
C_n = statewide net annual costs
L_{r2} = reduced leak per year in metric tons of CO_2E

In 2020 when the rule is in full effect the statewide net annual costs are expected to result in a savings of approximately $19 million ($20 million savings for large facilities, $0.3 million cost for medium facilities, and $0.2 million cost for small facilities) with reduced emissions of 8 MMTCO2E (4, 3, 1 MMTCO2E for large, medium, and small facilities, respectively) and a cost-effectiveness of approximately $5/$MTCO_2E$ savings for large, approximately break even for medium and small facilities ($0.08/MTCO2E cost for medium and $0.26/$MTCO_2E$ cost for small) with an overall average of $2/$MTCO_2E$ savings.

Total cost summary – The total costs of the rule are calculated for calendar years 2011 through 2020 (estimated costs in the year 2020 are summarized in Table 7). New facilities and systems are assumed to exist for the entire year they enter service and costs are calculated for a given year from the beginning of the year.

The costs and cost-effectiveness for any given facility will be dependent on the size, design, number of refrigeration systems at the facility, and the quality of maintenance and repair. A facility that quickly locates and repairs leaks will reduce the amount of refrigerant leaked when a leak occurs and save more refrigerant and

therefore, receive more of the cost benefits than a facility that is not as vigilant. It will also be more cost effective for a facility to construct their refrigeration system and make repairs using high quality parts so that leak occurrences are minimized.

Table 7: Statewide average annual cost of Stationary Refrigeration System Registration and Leak Repair (§ 95383) for the year 2020

	Annual cost (HFC plus ODS systems) ($ millions)	Annual cost (HFC systems only) ($ millions)
Recurring Annual Costs		
Implementation	$2.4	$2.0
Reporting and recordkeeping	$7.0	$6.4
Leak inspection	$21.0	$19.7
Automatic leak detection and monitoring		
Capital and installation cost	$4.1	$3.2
Annual maintenance	$3.2	$2.5
Leak Repair* (labor, parts, and refrigerant recharge)	$11.3	$10.2
Gross cost	$49.0	$44.0
Refrigerant savings	$68.1	$56.8
Net cost	$19.1 savings	$12.8 savings
Emissions reductions	8 MMTCO2E	7 MMTCO2E
Cost-effectiveness	$2/MTCO$_2$E savings	$2/MTCO$_2$E savings

*Leak repairs provided as 5% real discount rate cost of funds per year (see text for details)

Table 8 presents the costs to 'average' facilities. Implicit in Table 8 is the assumption that evacuation equipment, already required by federal rules for ODS system repairs, is already available and could be employed for recovery of all refrigerants. As a result, the proposed rule is not anticipated to result in additional

Table 8: Example average costs to average facilities

	Facilities with small systems	**Facilities with medium systems**	**Facilities with large systems**
Annual implementation fee	$0	$170	$370
Annual reporting and recordkeeping costs	$115	$422	$488
Automatic leak detection annual audit, quarterly inspection, or annual inspection costs	$375	$1,500	$300
Automatic leak detection capital costs	N/A	N/A	$1,830/year ($16,260 annualized over 12 years)*
Automatic leak detection operational costs	N/A	N/A	$1,440
Leak repair costs	$161	$677	$984
Total gross cost	$651	$2,770	$5,410
Refrigerant savings	$637	$2,740	$14,130
Total net annual costs	$14	$30	$8,720 savings

*Multiple monitoring systems since the average large facility has multiple large systems

costs for evacuation equipment. For all labor estimates an hourly labor rate of $75 is used. The average facility with small systems has approximately 5 systems, the average facility with medium systems has approximately 5 systems, and the average facility with large systems has approximately 2 systems (number of systems rounded for clarity, actual average number used in calculations). Repair costs included in the analyses represent 5% of the total cost of making the repair (parts, labor, and refrigerant recovery plus the refrigerant needed to recharge the system based on the modeled leak amount) per year to reflect the real discount rate cost of funds to do the repairs immediately upon the first indication of a leak rather than at a later date. Costs also include the percent of systems that leak in a given year as described in Appendix B (on average, approximately 68% of large systems, 37% of medium systems, and 22% of small systems will leak and require repairs each year). The impact on the average facility with small, medium, or large refrigeration systems is projected to be a net cost of $14, $30, and a savings of $8,720 respectively with an overall average impact of the program of a net savings of $670 per facility.

4. Example Case Studies

The analysis of potential emission reductions and costs is based on the average leak rate for an entire population of refrigeration systems and the resulting annual emissions, in contrast to the exact emissions that would result from a single refrigerant leak incident. As an example, a refrigeration system with a refrigerant charge of 2,000 pounds that has a 10% annual refrigerant leak rate would leak 200 pounds of refrigerant over a one-year period if it were not repaired. If detected promptly and repaired within 14 days of detection the actual emissions from this specific leak would be reduced to less than eight pounds – less than ½ of one percent of the full charge. In this example refrigerant savings would amount to over $2,000.

Several scenarios have been calculated to illustrate how individual facilities may be impacted by the proposed regulation. Although the rule is expected to go into effect in 2011, there will be a phase-in period. The case studies are based on the year 2020 because it allows for comparison with the statewide emission reduction targets specified in AB 32 and because all aspects of the rule will be in effect at all facilities subject to the regulation. These scenarios are described in the bullets that follow and then summarized in Table 9. Since it is assumed that the leaking systems will have to eventually be repaired to continue to operate without regard to this rule, the repair costs in the model are based on the real discount rate cost of funds (estimated at an annual rate of 5% per year of the cost of the repair) to do the repairs immediately upon the first indication of a leak rather than at a later date when the leak gets to the point of affecting the operation of the system. Other key assumptions including the assumed leak rate as well as the leak rate following repair are discussed in Appendix B.

These case studies are based on actual facility configurations encountered during development of the rule and average leak rates, etc. from the emission inventory for the types and sizes of equipment at these facilities. The case studies were also calculated with the actual reported refrigerant leaks. The results for the actual data are consistent with the average results; however, they are highly variable from year to year based on the facility's annual performance. The average results are presented to be more widely representative of facility types and configurations.

- A supermarket with a single large system with a total refrigerant charge of 3,000 pounds that combines all refrigeration and air-conditioning loads of the store. (Although air-conditioning systems are not included in the proposed rule, systems that combine both refrigeration and air-conditioning functions would be included in the rule.)
- A supermarket with four medium systems totaling 4,400 pounds of refrigerant to handle all combined refrigeration and air-conditioning loads of the store.
- A dairy distributor with two medium systems (800 pounds and 1,200 pounds).
- A pharmacy with one small refrigeration system (72 pounds).

Table 9: Case study example costs (2020)

	Annual reporting and recordkeeping costs and system inspections / audits costs	**Annual implement-ation fees**	**Annual monitoring system capital and operating costs**	**Expected annual repair costs ***	**Total gross annual costs**	**Annual refrigerant savings**	**Net annual costs**	**Cost-effective-ness ($/ $MTCO_2E$)**
Supermarket with 1 large system (3,000 lbs total charge)	$400	$370	$1,640	$420	$2830	($3,780)	($948)	($2)
Supermarket with 4 medium systems (4,400 lbs total charge)	$1,540	$170	$0	$800	$2,520	($2,610)	($97)	($0)
Dairy distributor with 2 medium systems (2,000 lbs total charge)	$780	$170	$0	$380	$1,320	($1,190)	$140	$1
Pharmacy with 1 small refrigeration system (72 lbs total charge)	$100	$0	$0	$30	$130	($75)	$50	$8

* 5% per year real discount rate cost of total funds for making repairs immediately after identifying a leak rather than at a later date

5. Economic Cost and Cost Savings Estimates (Refrigerant Sale, Use, and Disposal)

The cost and economic impacts specific to the Refrigerant Use, Sale, and Disposal component (Table 10) are based on requirements and prohibitions specific to California refrigeration and motor vehicle air conditioning (MVAC) and stationary heating, ventilation and air-conditioning (HVAC) service providers and refrigerant reclaimers, distributors, and wholesalers.

The cost resulting from the refrigerant use, sale, and disposal component of the Refrigerant Management Program proposed rule are primarily borne by U.S. EPA certified technicians, refrigerant reclaimers, and refrigerant distributors or wholesalers.

Table 10: Statewide annual cost of Refrigerant Use, Sale, and Disposal (§ 95384) for the year 2020

	Annual cost (HFC plus ODS systems) ($ millions)	Annual cost (HFC systems only) ($ millions)
Refrigerant Distributor or Wholesaler Prohibitions, Reporting and Recordkeeping Costs	$0.094	$0.070
Refrigerant Reclaimer Reporting and Recordkeeping Costs	$0.095	$0.071
Total § 95384Cost	$0.189	$0.141

California Service Contractors & Certified Technicians - As leak repairs are required to be completed by U.S. EPA certified technicians the certification cost to a technician related to a repair will be borne by a facility or the certified technician. Other than cost already identified for affected facilities, the primary requirements are related to evacuation of R/AC systems and recovery of refrigerant from empty cylinders, these costs are assumed to be borne by facilities for payments for refrigerant leak repair services. Equipment evacuation is already required by federal regulation for U.S. EPA certified technicians that provide refrigeration and air-conditioning service using ODS. As the alternative to cylinder evacuation is intentional venting of refrigerant and intentional venting is prohibited by federal law, the proposed rule does not create any additional costs for cylinder evacuation. Evacuation equipment, already required by federal rules for ODS system repairs, is already available and could be employed for recovery of all refrigerants. The proposed rule is not anticipated to result in additional costs for evacuation equipment.

California Refrigerant Reclaimers - Pursuant to Title 40 of the Code of Federal Regulation, Part 82, §82.154 refrigerant sales for ODS are limited to 1) sales to certified technicians, or their employer, 2) sales for the purpose of resale to certified technicians or appliance manufacturers, or 3) sales of refrigerant in an appliance. The proposed rule maintains the same requirements and extends the requirement to all high-GWP gases. The U.S. EPA estimated the annual burden of these

requirements to total 8,882 hours. Many of the records required for the federal regulations would be required for all high-GWP gases as the refrigerant sales would be to the same certified technicians and appliance manufacturers. But, to be conservative if the ARB assumes the same burden and reduces the amount to reflect only California (~12%), the estimated burden would be 1,066 hours or approximately $80,000 annually at $75 per hour.

Based on federal regulations refrigerant reclaimers reclaiming ODS must maintain records of the names and addresses of persons sending them material for reclamation and the quantity of material sent to them for reclamation. This information must be maintained on a transactional basis. Pursuant to Title 40 of the Code of Federal Regulation, Part 82, §82.166, within 30 days of the end of the calendar year, reclaimers must report to the U.S. EPA the total quantity of material sent to them that year for reclamation, the mass of refrigerant reclaimed that year, and the mass of waste products generated that year. Reporting requirements in the proposed regulation in substantial part are already required by federal regulations for ODS. In the determination of costs for reclaimer reporting, the U.S. EPA estimated that reporting required a total of five hours annually. At five hours and approximately 40 reclaimers in California additional reporting costs as a result of this rule are anticipated to be minimal at approximately $15,000 per year, approximately $375 for reclaimer per year.

California Refrigerant Distributors and Wholesalers - Based on federal regulations, Title 40 of the Code of Federal Regulation, Part 82, §82.166, refrigerant wholesalers who sell ODS refrigerants must retain invoices that indicate the name of the purchaser, the date of sale, and the quantity of refrigerant purchased. Although reporting is required under the proposed regulation, while it is not required by federal regulations, the reporting for distributors and wholesalers is a simple annual inventory report of the total refrigerant shipped to certified technicians and to reclaimers. The annual report would consist primarily of a summary of recordkeeping required in significant part by federal regulations. Based on similar reporting requirements, using the U.S. EPA reclaimer reporting estimate of five hours annually and approximately 250 distributors in California additional reporting costs for the proposed annual report requirement are anticipated to be minimal at approximately $94,000 per year, approximately $375 per distributor/wholesaler per year.

6. Conclusion

In summary (Table 11), the refrigerant management rule will significantly reduce the emissions of high-GWP GHG in California, is technologically feasible, and will achieve emissions reductions at an average cost-effectiveness of a savings of about $2/MT$CO_2$E and an average savings of approximately $700 per facility per year.

Table 11: Statewide annual cost of the entire proposed rule for the year 2020

	Annual cost (HFC plus ODS systems) ($ millions)	Annual cost (HFC systems only) ($ millions)
Net Costs: § 95383. General Requirements for Stationary Refrigeration System Registration and Leak Repair (Table 8)	$19.1 savings	$12.8 savings
Net Costs: § 95384. General Requirements for Refrigerant Use, Sale, and Disposal (Table 10)	$0.2	$0.1
Entire Rule Net cost	$18.9 savings	$12.7 savings
Proposed Rule Emissions Reductions	8 MMTCO2E	7 MMTCO2E
Proposed Rule Cost-effectiveness	$2/MTCO$_2$E savings	$2/MTCO$_2$E savings